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Lab project aims to make wind power more efficient

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Researchers at **Lawrence Livermore National Laboratory** are measuring and analyzing the shifting wind currents that pass over the jumbled hills and ravines between Livermore and Tracy in order to make wind farms better at predicting how much electrical energy they can provide to the power grid.

As they progress, they are helping explain the dynamics of the lower atmosphere in a way that could lead to advances in other areas, ranging from basic weather forecasting to predicting the growth of wildland fires.

Optical devices called LIDAR enable the researchers to "see" the swirling wind as it speeds up, slows down and forms turbulence that can damage wind turbines, according to Jeff Mirocha, lead scientist for the Lab's wind energy projects.

The area of study is near the boundary of Site 300, the Lab's explosives testing site. That puts it adjacent to the big commercial wind power development in the Altamont, so they are examining real-life conditions for wind power farms in complex terrain that is found widely throughout California.

The Lab also has a 170-foot weather tower, required by federal rules for Site 300, with modern instruments for recording wind speed, humidity, solar radiation and other features of modern meteorology that may be helpful in wind research.

Mirocha described the Lab's research effort last week to the Valley Study Group meeting in Pleasanton.

The Site 300 project is part of a larger wind power effort by the Lab, supported by the U.S. Department of Energy. Livermore researchers are involved in cooperative projects with industry as well as collaborations with colleagues from the University of Colorado, the National Renewable Energy Lab and others to improve the efficiency of wind power around the country.

The wind power stakes are large, nationally and within California. Wind power accounts for more than 40,000 megawatts of generating capacity in the U.S., now the world's second leading wind energy producer after being overtaken last year by China.

The Department of Energy has a goal of increasing wind power from the present one percent to 20 percent of U.S. electrical capacity by 2030. That means about 300,000 megawatt generating capacity in another 19 years, a "very aggressive" target, in Mirocha's words.

Among U.S. states, California ranks third in wind energy capacity, after Texas and Iowa. California has a little more than 3,000 megawatts installed capacity and another 18,000 megawatts planned or being built. (Texas has more than 8,000 megawatts installed, Iowa 3,700.)

California pioneered commercial wind farms. The Altamont installation east of Livermore remains the largest concentration of wind turbines in the world, but the turbines there are mostly small and old, with a modest capacity of 576 megawatts from nearly 5,000 turbines. By contrast, the newer Tehachapi installation has nearly double the capacity from fewer than 3,000 turbines.

At Altamont and elsewhere, older wind turbines are gradually being replaced with larger, taller ones. Larger means they catch more wind, and taller means they usually are spun by faster wind. The benefit of this kind of change is great, Mirocha pointed out, because wind energy increases with area swept by the rotor arms and by the cube of the wind speed; that is, twice the speed means eight times the energy.

Whatever the construction, winds blowing along the surface of the earth – the atmospheric "boundary layer" – produce extremely complex currents and eddies. A typical forecast of "15 mile winds from the northwest" is not precise enough. For wind power to reach its full potential, the details need to be better understood.

An unexpected drop in rotor speeds can undercut the operation of a wind farm, whose operator needs to be confident of giving realistic estimates of the electricity the farm will contribute to the grid over the next hours and days.

Wind farms sometimes generate 20 percent less electricity than was promised to the electrical grid because winds shift or weaken as they approach wind turbines, according to some publications.

The gap between what is promised and what is delivered can be challenging for a grid operator who has to make up the difference from other sources. Under certain circumstances, the wind farm operator can face financial penalties.

For the future, as wind power grows, wind farms should be situated in places where boundary layer dynamics are understood and predictable.

The technical problems are challenging for a variety of reasons. Mirocha notes that boundary layer changes occur on "an incredibly wide range of time scales" that matter to wind energy. Turbulence that can affect efficiency and even damage turbine blades can appear in a fraction of a second. Solar heating follows a day-and-night pattern, while weather fronts can move through and last for days. These all happen against the backdrop of seasonal change, and there are even longer lasting phenomena like El Nino and La Nina years, and climate change.

Studying air currents isn't easy, in part because there are invisible to ordinary sensing equipment. The LIDAR (light detection and ranging) instruments at Site 300 use detectable color changes that occur when visible laser beams bounce off microscopic air particles moving in various directions.

The focus of wind power research at Site 300 is collecting data on wind currents in great detail, day and night. Site 300 terrain is similar to much of the rest of California, so conclusions and models drawn from there will be widely applicable.

The Laboratory will also draw on its powerful computer resources and extensive modeling experience to develop pictures of wind flow with higher resolution than has been available previously.

The depth of the boundary layer changes depending on the temperature and other variables, but roughly speaking it is the lowest 500 to 1,000 feet of the atmosphere where the air motion ranges from practically stationary at ground level to steadier winds higher up.

Because the wind tends to blow faster at 200 or 300 feet above the ground that at 50 or 100 feet, new commercial wind turbines are generally made to operate at that level, Mirocha said. A modern new wind turbine has rotor blades 100 feet long or more and generates up to 2 megawatts. The current largest is a German model that generates up to 7.5 megawatts at more than 400 feet above the ground.

Much larger designs are on the books, according to Mirocha. They will require installation at sea, in part because of the logistics of transporting very heavy parts and in part because of environmental concerns on land. Another advantage over the ocean is that the atmospheric boundary layer has fewer severe instabilities and is generally better understood than over the land, he said. Britain, Denmark, Norway and Germany are among the countries with operating wind farms at sea, and the U.S. anticipates building them as well.